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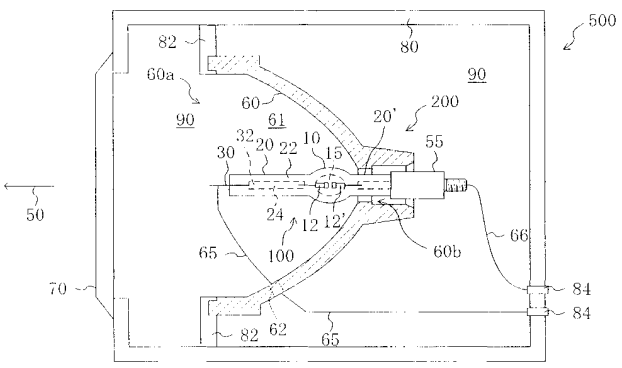
## (54) Lamp unit and image projection apparatus

(57) A lamp unit (500,600,700,800,900) includes a lamp (200) provided with a mirror (60) and a housing (80) for holding the lamp (200) provided with a mirror. The lamp (200) provided with a mirror includes a discharge lamp (100) including a luminous bulb (10) in which a luminous material is enclosed and a pair of electrodes (12,12') are opposed to each other in the luminous bulb (10); and a pair of sealing portions (20,20') for sealing a pair of metal foils (24) electrically connected to the pair of electrodes (12,12'), respectively; and a reflecting mirror (60) for reflecting light emitted from the discharge lamp (100) and having a front opening (60a) for emitting the reflected light. The lamp (200) provided with a mirror (60) is formed so as to have a non-airtight structure. The housing (80) includes a transmission window (70) made of a material for transmitting light emitted from the front opening (60a) and positioned forward in the emission direction (50) of the front opening (60a) of the reflecting mirror (60).

FIG. 1

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## Description

### BACKGROUND OF THE INVENTION

**[0001]** The present invention relates to lamp units. In particular, the present invention relates to lamp units used as a light source for an image projection apparatus such as a liquid crystal projector or a digital micromirror device (DMD) projector.

**[0002]** In recent years, an image projection apparatus such as a projector using a liquid crystal projector or a DMD has been widely used as a system for realizing large-scale screen images. A high-pressure discharge lamp having a high intensity has been commonly and widely used in such an image projection apparatus. For the light source of the image projection apparatus, light is required to be concentrated on an imaging device included in the optical system of the projector, so that in addition to high intensity, it is also necessary to achieve a light source close to a point light source. Therefore, among high-pressure discharge lamps, a short arc ultra high-pressure mercury lamp that is close to a point light and has a high intensity has been noted widely as a promising light source. The short arc ultra high-pressure mercury lamp can be used as a light source for projectors in the form of a lamp provided with a mirror in combination with a reflecting mirror.

**[0003]** Referring to FIG. **7,** a conventional lamp **1200** provided with a mirror including a short arc ultra high-pressure mercury lamp **1000** will be described. FIG. 7 is a schematic top view of a lamp **1200** provided with a mirror including a combination of an ultra high-pressure mercury lamp 1000 and a reflecting mirror **60**.

**[0004]** The lamp **1200** provided with a mirror includes a lamp **1000** and a reflecting mirror **60** for reflecting light emitted from the lamp **1000**. The lamp **1000** includes a substantially spherical luminous bulb **110** made of quartz glass, and a pair of sealing portions (seal portions) **120** and **120'** made of also quartz glass and connected to the luminous bulb **110**. A discharge space **115** is inside the luminous bulb **110.** A mercury in an amount of, for example, 150 to 250mg/cm$^3$ as a luminous material, a rare gas (e.g., argon with several tens kPa) and a small amount of halogen are enclosed in the discharge space **115.** A pair of tungsten electrodes (W electrode) **112** and **112'** are opposed with a certain distance (e.g., about 1.5mm) in the discharge space **115.**

**[0005]** The W electrode **112** is welded to a molybdenum foil (Mo foil) **124** in the sealing portion **120**, and the W electrode **112** and the Mo foil 124 are electrically connected. The sealing portion **120** includes a glass portion **122** extended from the luminous bulb **110** and the Mo foil **124**. The glass portion **122** and the Mo foil **124** are attached tightly so that the airtightness in the discharge space **115** in the luminous bulb **110** is maintained. An external lead (Mo rod) **130** made of molybdenum is joined to one end of the Mo foil **124** by welding, and the Mo foil **124** and the external lead **130** are electrically connected. The configurations of the W electrode **112'** and sealing **120'** are the same as those of the W electrode **112** and sealing **120**, so that description thereof will be omitted.

**[0006]** Next, the operational principle of the lamp **1000** will be described. When a start voltage is applied to the W electrodes **112** and **112'** via the external leads **130** and the Mo foils **124**, discharge of argon (Ar) occurs. Then, this discharge raises the temperature in the discharge space **115** of the luminous bulb **110**, and thus the mercury is heated and evaporated. Thereafter, mercury atoms are excited and become luminous in the arc center between the W electrodes **112** and **112'**. As the mercury vapor pressure of the lamp **1000** is higher, the emission efficiency is higher, so that the lamp having a higher mercury vapor pressure is suitable as a light source for an image projection apparatus. However, in view of the physical strength against pressure of the luminous bulb **110**, the lamp **1000** is used at a mercury vapor pressure of 15 to 25MPa.

**[0007]** The light emitted from the discharge lamp **1000** is reflected at the reflecting mirror **60** and emits in the emission direction **50**. The reflecting mirror **60** has a front opening **60a** on the side of the emission direction **50**. As described above, the mercury vapor pressure of the lamp **1000** is set to be within the range that is permitted by the physical strength against pressure of the luminous bulb **110** to prevent the damage of the lamp **1000**. However, for the purpose of preventing scattering, if the lamp should be broken, or preventing foreign matter from being directed toward the mirror, a front glass **170** is attached at the front opening **60a**. In other words, the lamp **1200** provided with a mirror is of an airtight structure, and scattered matters (glass pieces or mercury) generated, if the lamp should be broken, are prevented from going out. A lead wire **65** for external interconnection is electrically connected to the external lead **130** of the sealing portion **120**. The lead wire **65** for external interconnection is extended to the outside of the reflecting mirror **60** through an opening **62** for lead wire and electrically connected to an external circuit (e.g., ballast). The reflecting mirror **60** is attached to the sealing portion **120'** of the discharge lamp **1000**, and a lamp base **55** is attached to one end of the sealing portion **120'**.

**[0008]** When combining this lamp **1200** provided with a mirror with an optical system of an image projection apparatus (projector), as shown in FIG. **8A**, it is general to use a lamp unit **1500** in which the lamp **1200** is integrated with a lamp house **180** for holding the lamp **1200** provided with a mirror.

**[0009]** FIG. **8A** is a schematic view of the configuration of an image projection apparatus including the lamp unit **1500** and an optical system **190** (**191** to **193**), the lamp unit **1500** being partially cut away. FIG. **8B** is a perspective view viewed from the front of the lamp house **180** of the lamp unit **1500**. The lamp house **180** is a holding member provided with an opening **180a** for

emitting light at front, and has a non-airtight structure (having a L-shape in the example of FIGS. **8A** and **8B**). The lamp house **180** is attached to a predetermined position of the image projection apparatus, so that the lamp unit **1500** can be combined with the optical system **190** of the image projection apparatus. The light emitted from the lamp unit **1500** first reaches an image display device **192** (e.g., DMD or liquid crystal device (LCD)) of the optical system **190** through a lens **191**, and then is projected with magnification to a screen (not shown) through a projection lens **193**.

**[0010]** Since the conventional lamp **1200** provided with a mirror has an airtight structure, heat generated from the lamp during lamp operation is contained inside the lamp **1200** provided with a mirror, so that the temperature inside the lamp **1200** provided with a mirror is increased. In other words, when the lamp is damaged, the scattered matters of the lamp may come out of the lamp, and therefore, in order to prevent the scattered matters from coming out and ensure the security of the lamp without fail, the lamp **1200** provided with a mirror is required to have an airtight structure. As a result, the temperature in the atmosphere in the inside 61 of the lamp **1200** provided with a mirror is increased during operation, which is accompanied by an increase in the temperature of the sealing portion **120**. Molybdenum constituting the Mo foil **124** of the sealing portion **120** has a property that it is oxidized at 350°C or more. Therefore, the high temperature of the lamp **1200** provided with a mirror causes oxidation of the Mo foil **124** (in particular, a welded portion between the Mo foil **124** and the external lead **130**), which causes the conductivity of the Mo foil **124** to be lost, so that the lamp **1200** provided with a mirror stops operating.

**[0011]** In the past, partially because the size of the lamp **1200** provided with a mirror was large, the inside **61** of the lamp **1200** provided with a mirror was comparatively large, so that the temperature increase in the inside **61** of the lamp **1200** provided with a mirror did not cause a large problem in most cases. Furthermore, because of a comparatively short lifetime of the lamp due to deterioration of the luminous portion **110** of the lamp or a comparatively low output of the lamp, the reliability of lamp operation comparatively can be guaranteed, even if the temperature increase occurs in the inside **61** of the lamp **1200** provided with a mirror.

**[0012]** However, nowadays, since the size of the lamp **1200** provided with a mirror is small, the extent of the temperature increase of the inside **61** of the lamp **1200** with a mirror is becoming large. In addition, with improvement of the characteristics of the luminous portion **110** of the lamp, a longer lamp lifetime (e.g., several thousands hours or more) can be provided on the product base. Therefore, in order to guarantee the reliability of lamp operation during a long period, the problem of the temperature increase of the inside **61** of the lamp **1200** provided with a mirror cannot be ignored. Furthermore, under the circumstances that the lamp having a higher output is under development, the temperature of the lamp **1200** provided with a mirror tends to be significantly increased by increasing the output of the lamp. Therefore, it seems that the problem of the temperature increase of the inside **61** of the lamp **1200** provided with a mirror becomes increasingly serious.

**[0013]** The inventors of the present invention found the following phenomenon. When the lamp **1200** provided with a mirror is incorporated into an optical system of a projector using, for example, a DMD, as a light source of the projector, a part of the light emitted from the lamp **1200** provided with a mirror is reflected by the optical system and is incident to the lamp **1200** provided with a mirror, which increases the temperature of the lamp **1200** provided with a mirror. In the case where such a phenomenon occurs, the reliability of lamp operation cannot be guaranteed, even if the lamp **1200** provided with a mirror has been designed with an estimation of the internal temperature of the lamp **1200** provided with a mirror based on the output of the lamp.

**[0014]** Furthermore, the inventors of the present invention examined the approach of making a hole in a part of the reflecting mirror **60** for the purpose of replacing the air in the inside **61** of the lamp **1200** provided with a mirror by the outside air. However, When a hole is made in a part of the reflecting mirror **60**, the luminous flux emitted from the lamp **1200** provided with a mirror is reduced because of a reduction in the area that reflects the light emitted from the lamp **1000**, and thus the optical performance of the lamp is degraded. Moreover, when a hole is made in a part of the reflecting mirror **60**, the lamp **1200** provided with a mirror is not of an airtight structure, which causes a problem in security.

## SUMMARY OF THE INVENTION

**[0015]** Therefore, with the foregoing in mind, it is a main object of the present invention to provide a lamp unit with improved reliability of its operation in which the temperature of the inside of the lamp provided with a mirror is suppressed.

**[0016]** A lamp unit of the present invention includes a lamp provided with a mirror and a house for holding the lamp provided with a mirror. The lamp provided with a mirror includes a discharge lamp including a luminous bulb in which a luminous material is enclosed and a pair of electrodes are opposed to each other in the luminous bulb; and a pair of sealing portions for sealing a pair of metal foils electrically connected to the pair of electrodes, respectively; and a reflecting mirror for reflecting light emitted from the discharge lamp and having a front opening for emitting the reflected light. The lamp provided with a mirror is formed so as to have a non-airtight structure. The house includes a transmission window made of a material for transmitting light emitted from the front opening and positioned forward in the emission direction of the front opening of the reflecting mirror.

**[0017]** It is preferable that the lamp provided with a

mirror has a non-airtight structure with the front opening of the reflecting mirror being open.

**[0018]** It is preferable that the house has a structure that can accommodate scattered matters when the discharge lamp is scattered to prevent the scattered matters from coming out.

**[0019]** It is preferable that the house includes an opening for replacing gas inside the house by gas outside the house.

**[0020]** It is preferable that the house has an airtight structure.

**[0021]** It is preferable that the house further includes a convection apparatus for cooling.

**[0022]** The transmission window can be made of glass or reinforced plastics.

**[0023]** It is preferable that the house is made of a metal.

**[0024]** In one embodiment of the present invention, the lamp unit is a lamp unit for image projection apparatus in which the optical axis of the discharge lamp coincides with the optical axis of the reflecting mirror.

**[0025]** In one embodiment of the present invention, the lamp unit is constituted as a replaceable unit as a light source for an image projection apparatus.

**[0026]** According to another aspect of the present invention, an image projection apparatus includes the above-described lamp unit, and an optical system using the lamp unit as a light source. The optical axis of the discharge lamp included in the lamp unit coincides with the optical axis of the lamp unit and the optical axis of the optical system.

**[0027]** In one embodiment of the present invention, the lamp unit is constituted as a replaceable unit as a light source for an image projection apparatus, and the optical system includes at least a lens and an image display device selected from the group consisting of digital micromirror device and a liquid crystal display device.

**[0028]** In the lamp unit of the present invention, the lamp provided with a mirror is formed so as to have a non-airtight structure, and a transmission window is provided in a house (housing) for holding the lamp provided with a mirror. Therefore, it is possible to move the gas inside the lamp provided with a mirror into other portions throughout the house, so that the temperature of the inside of the lamp provided with a mirror during lamp operation can be suppressed over the prior art. As a result, a lamp unit having improved reliability of lamp operation can be provided. Furthermore, since the temperature increase of the lamp provided with a mirror can be suppressed, a lamp unit having a long lamp lifetime can be provided. Furthermore, the transmission window is provided forward in the emission direction of the front opening of the reflecting mirror, so that the transmission window prevents the scattered matters from coming out, even if the scattered matters (e.g., glass pieces or mercury) generated at lamp breakage comes out from the front opening of the reflecting mirror. The lamp provided with a mirror included in the lamp unit of the present invention has a non-airtight structure with the front opening of the reflecting mirror being open, for example.

**[0029]** In the case where the house has a structure that can accommodate the scattered matters, the scattered matters generated at lamp breakage can be prevented from coming out from the lamp unit. Therefore, the security of the lamp unit can be improved further. When an opening for replacing gas in the inside by gas in the outside of the house is provided at least in an upper portion of the house in the vertical direction, the temperature increase of the inside of the lamp provided with a mirror can be suppressed more effectively. When the house has an airtight structure, no scattered matter generated at lamp breakage can come out. When the convection apparatus for cooling is provided in the house, the gas in the house can be convected forcefully, so that the temperature increase of the lamp provided with a mirror can be suppressed more effectively. The transmission window can be made of glass or reinforced plastics. When the house is made of a metal, the heat release properties of the lamp unit can be improved, so that the temperature increase of the lamp provided with a mirror can be suppressed more effectively.

**[0030]** According to the lamp unit of the present invention, the temperature increase of the lamp provided with a mirror during lamp operation can be suppressed. As a result, a lamp unit having improved reliability of lamp operation can be provided. Furthermore, since the temperature increase of the lamp provided with a mirror can be suppressed, a lamp unit having a long lamp lifetime (e.g., of five thousands hours to one million hours) can be provided.

**[0031]** This and other advantages of the present invention will become apparent to those skilled in the art upon reading and understanding the following detailed description with reference to the accompanying figures.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0032]**

FIG. **1** is a schematic view showing the configuration of a lamp unit **500**.

FIG. **2** is a view from the back of a reflecting mirror 60 of the lamp unit **500**.

FIG. **3** is a schematic cross-sectional view showing the configuration of a lamp unit **600**.

FIG. **4** is a schematic cross-sectional view showing the configuration of a lamp unit **700**.

FIG. **5** is a schematic cross-sectional view showing the configuration of the lamp unit **800**.

FIG. **6** is a schematic cross-sectional view showing the configuration of a lamp unit **900**.

FIG. **7** is a schematic view showing the configuration of a conventional lamp **1200** provided with a mirror.

FIG. **8A** is a schematic view showing the configuration of an image projection apparatus including a

conventional lamp unit **1500** and an optical system **190**.

FIG. **8B** is a schematic perspective view showing the configuration of a conventional lamp house **180**.

## DETAILED DESCRIPTION OF THE INVENTION

**[0033]** Hereinafter, embodiments of the present invention will be described with reference to the accompanying drawings. In the following drawings, for simplification, the elements having substantially the same functions bear the same reference numeral.

Embodiment **1**

**[0034]** Embodiment **1** of the present invention will be described with reference to FIGS. **1** and **2**. FIG. **1** is a schematic view showing the configuration of a lamp unit **500** of Embodiment **1**.

**[0035]** The lamp unit **500** includes a lamp **200** provided with a mirror and a house (lamp house) **80** for holding the lamp **200** provided with a mirror. The lamp **200** provided with a mirror includes a discharge lamp **100** and a reflecting mirror **60** for reflecting light emitted from the discharge lamp **100**. The lamp **200** provided with a mirror has a non-airtight structure in which a front glass is not provided at a front opening **60a** of the reflecting mirror **60**. In other words, the lamp **200** provided with a mirror has a non-airtight structure in which the front opening **60a** of the reflecting mirror **60** is open. Furthermore, the house **80** for holding the lamp **200** provided with a mirror has a transmission window **70** made of a material that transmits light emitted from the front opening **60a** in a portion forward in the emission direction **50** of the from opening **60a** of the reflecting mirror **60.** The house **80** serves to protect the lamp **200** provided with a mirror, in addition to serving to hold the lamp **200** provided with a mirror.

**[0036]** The discharge lamp **100** included in the lamp unit **500** includes a luminous bulb **10,** and a pair of sealing portions **20** and **20'** connected to the luminous bulb **10**. A discharge space **15** in which a luminous material **18** is enclosed is provided inside the luminous bulb **10**. A pair of electrodes **12** and **12'** are opposed to each other in the discharge space **15**. The luminous bulb **10** is made of quartz glass and is substantially spherical. The outer diameter of the luminous bulb **10** is, for example, about 5mm to 20mm. The glass thickness of the luminous bulb **10** is, for example, about 1mm to 5mm. The volume of the discharge space **15** in the luminous bulb **10** is, for example, about 0.01 to 1cc. In this embodiment, the luminous bulb **10** having an outer diameter of about 13mm, a glass thickness of about 3mm, a volume of the discharge space **15** of about 0.3cc is used. As the luminous material, mercury is used. For example, about 150 to 200mg /$cm^3$ of mercury, a rare gas (e.g., argon) with 5 to 20kPa, and a small amount of halogen are enclosed in the discharge space **15**.

**[0037]** The pair of electrodes **12** and **12'** in the discharge space **15** is arranged with a gap (arc length) of, for example, about 1 to 5mm (preferably about 1 to 3mm). As the electrodes **12** and **12'**, for example, tungsten electrodes (W electrodes) are used. In this embodiment, the W electrodes **12** and **12'** are arranged with a gap of about 1.5mm. The electrode axis (W rod) of the electrode **12** is electrically connected to the metal foil **24** in the sealing portion **20**. Similarly, the electrode axis of the electrode **12'** is electrically connected to the metal foil **24'** in the sealing portion **20'**.

**[0038]** The sealing portion **20** includes a metal foil **24** electrically connected to the electrode **12** and a glass portion **22** extended from the luminous bulb **10**. The airtightness in the discharge space **15** in the luminous bulb **10** is maintained by the foil-sealing between the metal foil **24** and the glass portion **22**. The glass portion **22** of the sealing portion **20** is made of quartz glass, for example. The metal foil **24** is a molybdenum foil (Mo foil), for example, and has a rectangular shape, for example. The sealing portion **20** has a circular shape in section, for example. The metal foil **24** is positioned substantially in the center of the sealing portion **20**. The metal foil **24** of the sealing portion **20** is joined to the electrode **12** by welding, and the metal foil **24** has an external lead **30** on the side opposite to the side that is joined to the electrode **12**. The external lead **30** is formed of, for example, molybdenum, and connected to the metal foil **24** at a connection portion **32** by welding. The configuration of the sealing portion **20'** is the same as that of the sealing portion **20**, so that the description thereof is omitted. One sealing portion **20** is arranged on the side of the front opening **60a** of the reflecting mirror **60** (on the side of the emission direction **50**), and the other sealing portion **20'** is fixed to the reflecting mirror **60**. A lamp base **55** is attached to an end of the sealing portion **20'**. The sealing portion **20'** and the reflecting mirror **60** are attached with, for example, an inorganic adhesive (e.g., cement) to form one unit.

**[0039]** The reflecting mirror **60** fixed to the sealing portion **20'** is designed to reflect the light radiated from the discharge lamp **100** such that the light becomes a parallel luminous flux, a condensed luminous flux converged on a predetermined small area, or a divergent luminous flux equal to that emitted from a predetermined small area. As the reflecting mirror **60**, a parabolic reflector or an ellipsoidal mirror can be used, for example. An opening **62** for a lead wire is provided in the reflecting mirror **60**, and the lead wire **65** for external interconnection is drawn out of the reflecting mirror **60** through the opening **62** for a lead wire. The lead wire **65** for external interconnection that is drawn out of the reflecting mirror **60** is electrically connected to a terminal **84** provided in the house **80**, and the terminal **84** is electrically connected to an external circuit (e.g., ballast). The lamp base **55** of the lamp **100** also is electrically connected to the terminal **84** through a lead wire 66 for external interconnection.

**[0040]** The reflecting mirror **60** is fixed to the house **80** with a mirror holding member **82**. There is no limitation regarding the mirror holding member **82**, as long as it can hold the reflecting mirror **60**. For example, the reflecting mirror **60** can be fixed to the house **80** with a connecting member (screw, bolt, nut, etc.). Alternatively, the reflecting mirror **60** can be fitted into the mirror holding member **82**. Furthermore, the reflecting mirror **60** and the mirror holding member **82** can be attached or adhered to each other, or the reflecting mirror **60** can be fixed to the house **80** with magnetic force.

**[0041]** In this embodiment, for the purpose of simplifying the configuration of the mirror holding member **82**, the reflecting mirror **60** is pressed to a part of the house **80**, utilizing the force of a band **86**, to constitute the mirror holding member **82**, as shown in FIG. **2**. FIG. **2** is a schematic view of the reflecting mirror **60** viewed from its back.

**[0042]** As shown in FIG. **2**, the band (e.g., wire) **86** is fixed at both ends with a band fixture **87**, and has a circular (ring-shaped) structure. A part of the band **86** can be hooked to a band fastener (buckle) **88**. With this configuration, the band **86** is set along the back surface of the reflecting mirror **60**, and the band **86** is hooked to the band fastener **88**, so that the reflecting mirror **60** easily can be fixed to the house **80**. The mirror holding member **82** shown in FIG. **2** easily can fix the lamp **200** provided with a mirror with a simple configuration, so that the mirror holding member **82** has a large advantage in assembling a lamp unit. It is preferable to provide a hook **89** for movement prevention for preventing the reflecting mirror **60** from moving after the reflecting mirror **60** is fixed.

**[0043]** Referring back to FIG. **1**, the transmission window **70** included in the house **80** is constituted by, for example, glass or reinforced plastics. The transmission window **70** is provided forward in the emission direction **50** of the front opening **60a** of the reflecting mirror **60**, and therefore even if the scattered matters(e.g., glass pieces or mercury) generated at lamp breakage comes out from the front opening **60a** of the reflecting mirror **60**, the transmission window **70** prevents the scattered matters from coming out. Therefore, in the lamp unit **500** of this embodiment, even if the lamp **200** provided with a mirror that is not provided with the front glass at the front opening **60a** of the reflecting mirror **60** is used, the transmission window **70** ensures the security of the lamp. In the lamp unit **500** of this embodiment, the temperature of the house **80** during lamp operation can be lower than that of the mirror **60** of the conventional lamp **1200** provided with a mirror shown in FIG. **7**, so that another advantage is that not only glass, but also reinforced plastics can be used preferably as the material for the transmission window **70**. In this embodiment, an opening is formed at the front of the house **80** positioned forward in the emission direction **50**, and the transmission window **70** is provided so as to cover the opening from the outside of the house **80**, but the present invention is not limited thereto, and the transmission window **70** is provided so as to cover the opening from the inside of the house **80**. Furthermore, the transmission window **70** may be provided in a part (e.g., central portion) or the entire portion of the front of the house **80** positioned forward in the emission direction **50**. In this embodiment, the house **80** is designed to have an airtight structure, so that even if the lamp **100** is broken and scattered matters (glass pieces or mercury) are generated, the scattered matters are prevented from coming out from the lamp unit **500**. In other words, the configuration of the house **80** can accommodate the scattered matters so as to prevent the scattered matters from coming out, so that the security of the lamp can be ensured further.

**[0044]** The house **80** is formed of, for example, a metal (e.g., aluminum, stainless steel, iron, etc.). Metals typically have high heat conductivity, so that metals can improve the heat release properties of the house **80** (lamp **200** provided with a mirror). Furthermore, in the case of the house **80** formed of metal, the house **80** can be reused easily so that this is advantageous in view of recycle of the resources. The volume of the inside **90** of the house **80** in this embodiment is, for example, about 800 to 2000$cm^3$. On the other hand, the volume of the inside **61** of the reflecting mirror **60** is, for example, about 200$cm^3$. Thus, the volume of the inside **90** of the house **80** can be four to 10 times as large as the volume of the inside **61** of the reflecting mirror **60**. According to the configuration of the lamp unit **100** of this embodiment, it is possible to reduce the temperature by about 10 to 50°C lower than that of the inside **61** of the conventional lamp **1200** provided with a mirror during lamp operation. In FIG. **1**, the inside **90** of the house **80** forward of the reflecting mirror **60** is in communication with the inside **90** of the house **80** backward of the reflecting mirror **60**, and the air in the inside **90** of the house **80** can move freely throughout the house **80**.

**[0045]** In this embodiment, the lamp **100** and the reflecting mirror **60** in the lamp unit **500** are designed so that their optical axes coincide with each other, so that the lamp unit **500** can be used preferably as the light source of an image projection apparatus. It is known that when the optical axis alignment is not satisfactory, image forming by the image projection apparatus is poor. For example, a dislocation of only 0.4mm in the optical axes reduces the brightness on the screen by up to about 60%. When the lamp unit **500** is used as a headlight of an automobile, strict alignment of the optical axes is not necessarily required because it only needs to illuminate forward.

**[0046]** Furthermore, when combining the lamp unit **500** with the optical system **190** (**191** to **193**) shown in FIG. **8** to constitute an image projection apparatus, the lamp unit **500** is designed so as to form a replaceable unit as the light source for an image projection apparatus, so that the lamp unit **500** very easily can be attached to the image projection apparatus or replaced. Furthermore, when setting the lamp unit **500** in a position for a

lamp unit installation in the image projection apparatus, in the case where the optical axis of the lamp unit **500** is designed to coincide with the optical axis of the optical system **190**, simply attaching or replacing the lamp unit **500** can complete the alignment of the optical axes.

**[0047]** According to the present invention, the lamp unit **500** is provided with the lamp **200** provided with a mirror having a non-airtight structure in which a front glass is not provided at the front opening **60a** of the reflecting mirror **60**, and therefore the air in the inside **61** of the lamp **200** provided with a mirror whose temperature is increased during lamp operation can convect (move), not only in the inside **61** of the lamp **200** provided with a mirror, but also in a wide range throughout the inside **90** of the house **80**. Therefore, the temperature increase in the lamp **200** provided with a mirror during lamp operation can be suppressed more than in the case of the conventional lamp **1200** provided with a mirror in which convention is caused only in the inside **61** of the reflecting mirror **60**. As a result, the reliability of the lamp operation can be improved further. Furthermore, since the lamp can be used in the state where the temperature increase in the lamp **200** provided with a mirror is suppressed, the lifetime of the lamp can be prolonged. Furthermore, the house **80** having the transmission window **70** can ensure the security of the lamp. In addition, the lamp unit **500** is a replaceable unit as a light source for an image projection apparatus, so that the lamp unit **500** can be attached to the image projection apparatus or replaced very easily. In the case where the lamp unit **500** is designed with the optical axis alignment taken into consideration when setting the lamp unit **500**, the optical axis alignment can be completed by attaching or replacing the lamp unit **500**.

**[0048]** In the lamp unit **500** of this embodiment, the house **80** having an airtight structure is used. However, it is possible to use the house **80** provided with the opening **81**, if the house **80** has a structure in which the scattered matters from the lamp **100** when the lamp is scattered are accommodated so as not to come out, as shown in FIG. **3**. In the lamp unit **600** shown in FIG. **3**, a lid portion **81a** covering the upper portion of the opening **81** so as to prevent the scattered matters from coming out from the opening **81** is formed in the house **80**.

**[0049]** The lid portion **81a** is spaced away from the outer wall of the house **80**, so that the air in the inside **90** of the house **80** is in communication with the outside air through the opening **81** and the gap between the lid portion **81a** and the house **80**. Therefore, even if the temperature of the air of the inside **90** of the house **80** is increased as a result of the temperature increase of the air in the inside **61** of the lamp **200** provided with a mirror during lamp operation, the air can be replaced by the outside air through the opening **81**. For this reason, the temperature increase of the lamp **200** provided with a mirror can be suppressed further. The air having a high temperature moves upward in the vertical direction by convection. Therefore, in order to replace the air in the inside **90** of the house **80** by the outside air efficiently, it is preferable to provide the opening **81** at least in an upper portion in the vertical direction of the house **80**.

**[0050]** It is sufficient to provide at least one opening **81**, but it is preferable to form a plurality of openings **81** in order to increase the efficiency of the replacement of the air in the inside of the house **80** by the outside air. In the case where the opening **81** is formed in a lower surface and/or a side, in addition to the upper surface of the house **80**, the configuration can be that the openings **81** are provided in a portion having the lowest temperature and in a portion having the highest temperature, so that convection can be caused efficiently. As a result, it is possible to replace the air in the inside **90** more effectively.

**[0051]** In the lamp unit **600**, the lid portion **81a** is provided in the opening **81** of the house **80** to form a configuration that accommodates scattered matters to prevent the scattered matters from coming out. However, there is no particular limitation regarding the configuration of the house **80.** For example, a net that prevents the scattered matters from coming out may be provided.

Embodiment 2

**[0052]** The lamp unit **500** of Embodiment **1** can be modified to form a lamp unit **700** in which a heat sink **56** is provided in the lamp base **55** of the lamp **100** for the purpose of further reducing the temperature increase of the lamp **200** provided with a mirror. FIG. **4** is a schematic view of the configuration of the lamp unit **700** of this embodiment.

**[0053]** The heat sink **56** attached to the lamp **100** of the lamp unit **700** is thermally coupled to the lamp **100** and has a function to suppress the temperature increase of the lamp by enlarging the surface area. The heat sink **56** is, for example, a fin for radiation, and is made of a material having a high heat conductivity (e.g., metal materials such as Al and Cu). The temperature increase of the lamp **200** provided with a mirror during lamp operation can be suppressed more effectively by providing the heat sink **56**. It is possible to provide the opening **81** for replacing the air in the inside **90** of the house **80** by the outside air, as in the lamp unit **600** shown in FIG. **3**, also in the case where the heat sink **56** is provided.

**[0054]** Furthermore, when further effective suppression of the temperature increase of the lamp **200** provided with a mirror is desired, as shown in the lamp unit **800** of FIG. **5**, a convection apparatus **95** for cooling can be provided in the house **80** of the lamp unit **500** of Embodiment **1**. The convection apparatus **95** for cooling is, for example, a cooling fan for forcefully causing the air in the inside **90** of the house **80** to convect. The convection apparatus **95** for cooling is coupled to the house **80** via, for example, a pipe **92**, and the air in the inside **90** of the house **80** is forcefully convected and cooled by the convection apparatus **95** for cooling. As a result, the temperature increase of the lamp **200** provided with a

mirror can be suppressed more effectively. In the lamp unit **800**, it is possible to reduce the temperature by about 50°C to about 100°C from that of the inside **61** of the conventional lamp **1200** provided with a mirror during lamp operation. Although one pipe **92** is provided in FIG. **5**, separate pipes for drawing-in and drawing-out can be used. The convection apparatus **95** for cooling has a function to cool by forcefully convecting the air of the inside **90** of the house **80**, so that the convection apparatus **95** for cooling can be attached to the house **80** of either the lamp unit **600** or **700**.

**[0055]** The configuration in which the temperature of the gas is directly cooled by providing a cooler in the convection apparatus **95** for cooling, as well as cooling by the cooling fan is preferable to suppress the temperature increase of the lamp **200** provided with a mirror. Furthermore, it is possible to use, for example, an inert gas ($N_2$, etc.) instead of the air in the inside **90** of the house **80.** Furthermore, it is possible to provide a pipe **92** connected to the convection apparatus **95** for cooling on the back of the reflecting mirror **60** of the lamp **200** provided with a mirror and to allow a coolant (e.g., water) to flow through the pipe **92** for the purpose of directly reducing the temperature increase of the lamp **200** provided with a mirror. In other words, it is possible to forcefully reduce the temperature of the lamp **200** provided with a mirror by the approach of allowing a coolant to flow. It seems that such an approach of forcefully suppressing the temperature increase of the lamp provided with a mirror is more effective when used for the lamp provided with a mirror that has been developed for higher wattage.

Other embodiments

**[0056]** The lamp units of the above embodiments can reduce the temperature in the inside of the lamp provided with a mirror from that of the conventional configuration, so that it is possible to reduce the length of the metal foil **24** in the sealing portion **20** that also serves to release the heat in the lamp **100**. This can reduce the size of the lamp **100**, and therefore it is possible to provide a lamp unit including a smaller lamp **200** provided with a mirror. Furthermore, the temperature in the inside of the lamp provided with a mirror during lamp operation can be reduced from that in the conventional lamp, which may make it possible to constitute the metal foil made of a material other than molybdenum.

**[0057]** Furthermore, the above embodiments have been described by taking the non-airtight lamp **200** provided with a mirror without the front glass in the front opening **60a** of the reflecting mirror **60** as an example. However, a non-airtight lamp **200'** provided with a mirror as shown in FIG. **6** can be used, where a front glass **170** is provided in the front opening **60a**, and an opening (through hole) **60c** for drawing the air in and out is provided in a part of the reflecting mirror **60**. In the case of the configuration FIG. **6**, the opening **60c** is provided in a position that is most distant from the luminous bulb **10** of the lamp **100** and where the efficiency of the light reflection is not reduced very much. For example, a plurality of openings are formed in a position near the front opening **60a** of the reflecting mirror **60**. In the case of the lamp unit **900** having the configuration shown in FIG. **6**, there are substantially two front glasses, that is, the transmission window **70** of the house **80** and the front glass **170** of the lamp **200** provided with a mirror, so that the effect of preventing scattering forward can be large.

**[0058]** In the above embodiments, mercury lamps employing mercury as the luminous material have been described as an example of the discharge lamp. However, the present invention can apply to any discharge lamps in which the airtightness of the luminous bulb is maintained by the sealing portion (seal portion). For example, the present invention can apply to a discharge lamp enclosing a metal halide such as a metal halide lamp.

**[0059]** Furthermore, in the above embodiments, the case where the mercury vapor pressure is about 20MPa (the case of so-called ultra high-pressure mercury lamp) has been described. However, the present invention can apply to a high-pressure mercury lamp where the mercury vapor pressure is about 1MPa or a low pressure mercury lamp where the mercury vapor pressure is about 1kPa. Furthermore, the lamp can be of a short arc type where the distance (arc length) between the pair of electrodes **12** and **12'** is short, or the distance can be longer than that. The discharge lamps of the above embodiments can be used by either alternating current lighting or direct current lighting.

**[0060]** The lamp units in the above embodiments can be used preferably as the light source of a projector. In addition, the lamp units also can be used as the light source for ultraviolet ray steppers, the light source for sports stadiums, the light source for headlights for automobiles or floodlights illuminating road signs.

**[0061]** The invention may be embodied in other forms without departing from the spirit or essential characteristics thereof. The embodiments disclosed in this application are to be considered in all respects as illustrative and not limiting. The scope of the invention is indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are intended to be embraced therein.

## Claims

**1.** A lamp unit comprising:

a lamp provided with a mirror and a house for holding the lamp provided with a mirror,

wherein the lamp provided with a mirror comprises:

a discharge lamp including a luminous bulb in

which a luminous material is enclosed and a pair of electrodes are opposed to each other in the luminous bulb; and a pair of sealing portions for sealing a pair of metal foils electrically connected to the pair of electrodes, respectively; and

a reflecting mirror for reflecting light emitted from the discharge lamp and having a front opening for emitting the reflected light,

the lamp provided with a mirror is formed so as to have a non-airtight structure, and

the house includes a transmission window made of a material for transmitting light emitted from the front opening and positioned forward in the emission direction of the front opening of the reflecting mirror.

**2.** The lamp unit according to claim 1, wherein the lamp provided with a mirror has a non-airtight structure with the front opening of the reflecting mirror being open.

**3.** The lamp unit according to claim 1, wherein the house has a structure that can accommodate scattered matters when the discharge lamp is scattered to prevent the scattered matters from coming out.

**4.** The lamp unit according to claim 1, wherein the house includes an opening for replacing gas inside the house by gas outside the house.

**5.** The lamp unit according to claim 3, wherein the house has an airtight structure.

**6.** The lamp unit according to claim 5, wherein the house further includes a convection apparatus for cooling.

**7.** The lamp unit according to claim 1, wherein the transmission window is made of glass or reinforced plastics.

**8.** The lamp unit according to claim 1, wherein the house is made of a metal.

**9.** The lamp unit according to claim 1, wherein the lamp unit is a lamp unit for image projection apparatus in which an optical axis of the discharge lamp coincides with an optical axis of the reflecting mirror.

**10.** The lamp unit according to claim 9, wherein the lamp unit is constituted as a replaceable unit as a light source for an image projection apparatus.

**11.** An image projection apparatus comprising the lamp unit of claim 1, and an optical system using the lamp unit as a light source,

wherein an optical axis of the discharge lamp included in the lamp unit coincides with an optical axis of the lamp unit and an optical axis of the optical system.

**12.** The image projection apparatus according to claim 11,

wherein the lamp unit is constituted as a replaceable unit as a light source for an image projection apparatus, and

the optical system includes at least a lens and an image display device selected from the group consisting of digital micromirror device and a liquid crystal display device.

FIG. 1

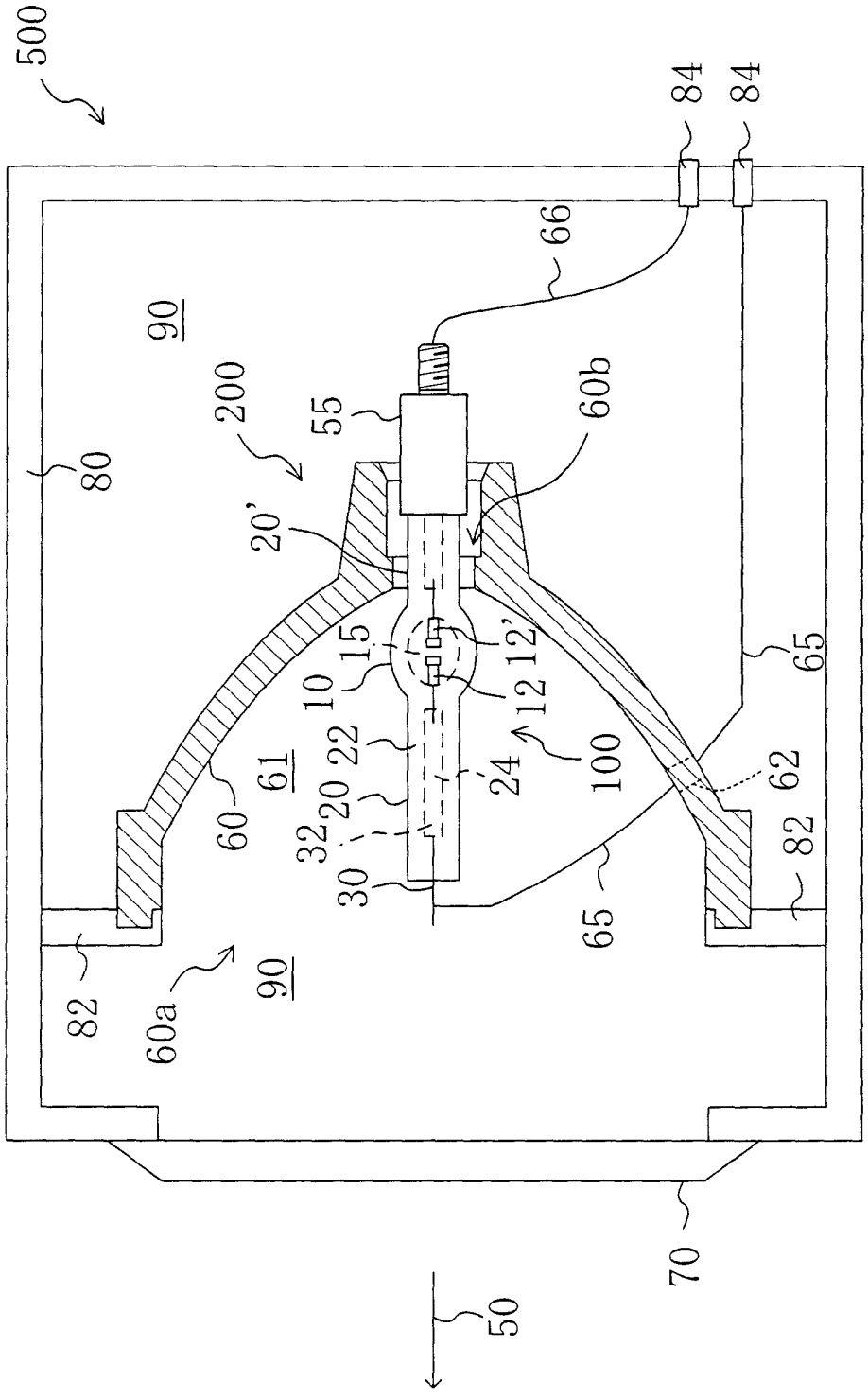

500
84
84
66
90
200
55
60b
80
20'
15
12'
10
12
22
24
100
61
60
20
62
32
30
82
65
65
82
90
60a
70
50

FIG. 2

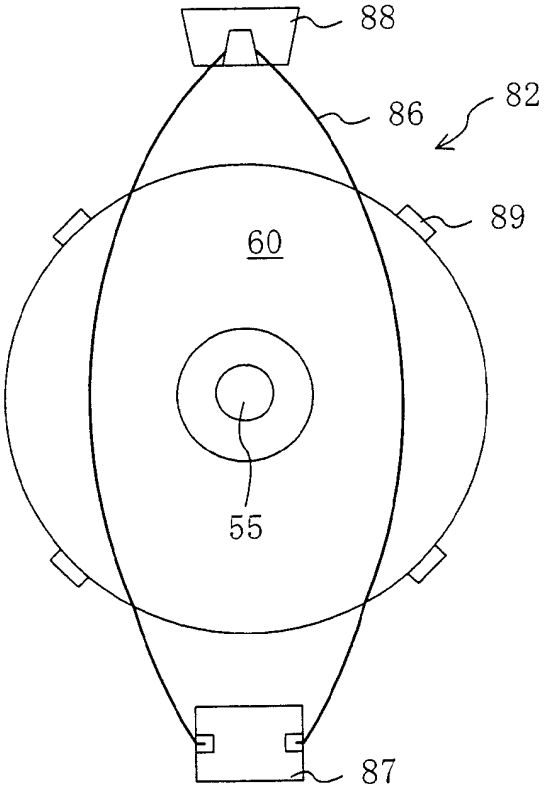
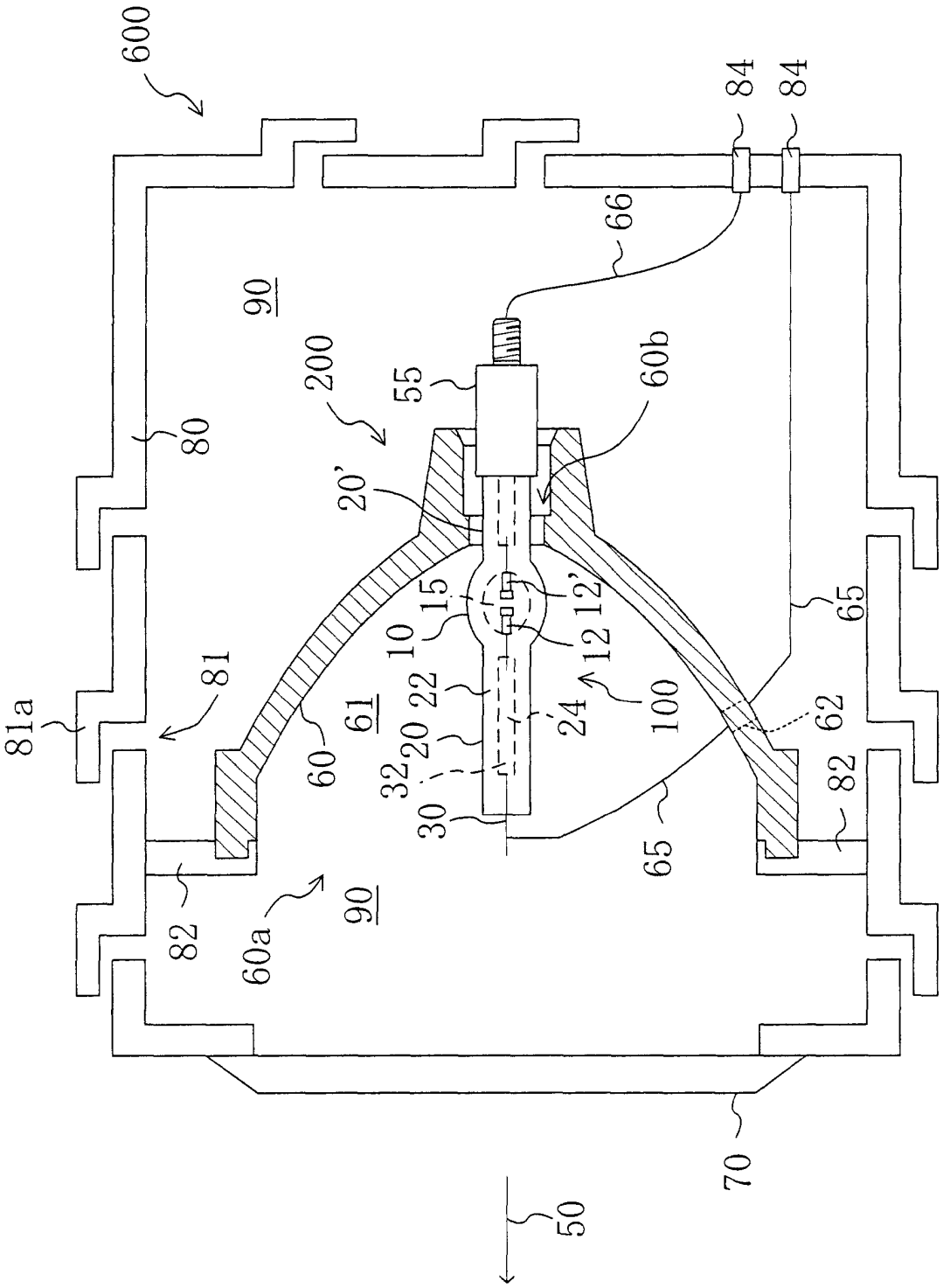


FIG. 3


600
84
84
66
90
200
55
60b
80
20'
15
12'
10
12
65
81
81a
61
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82
30
65
82
90
60a
70
50

FIG. 4

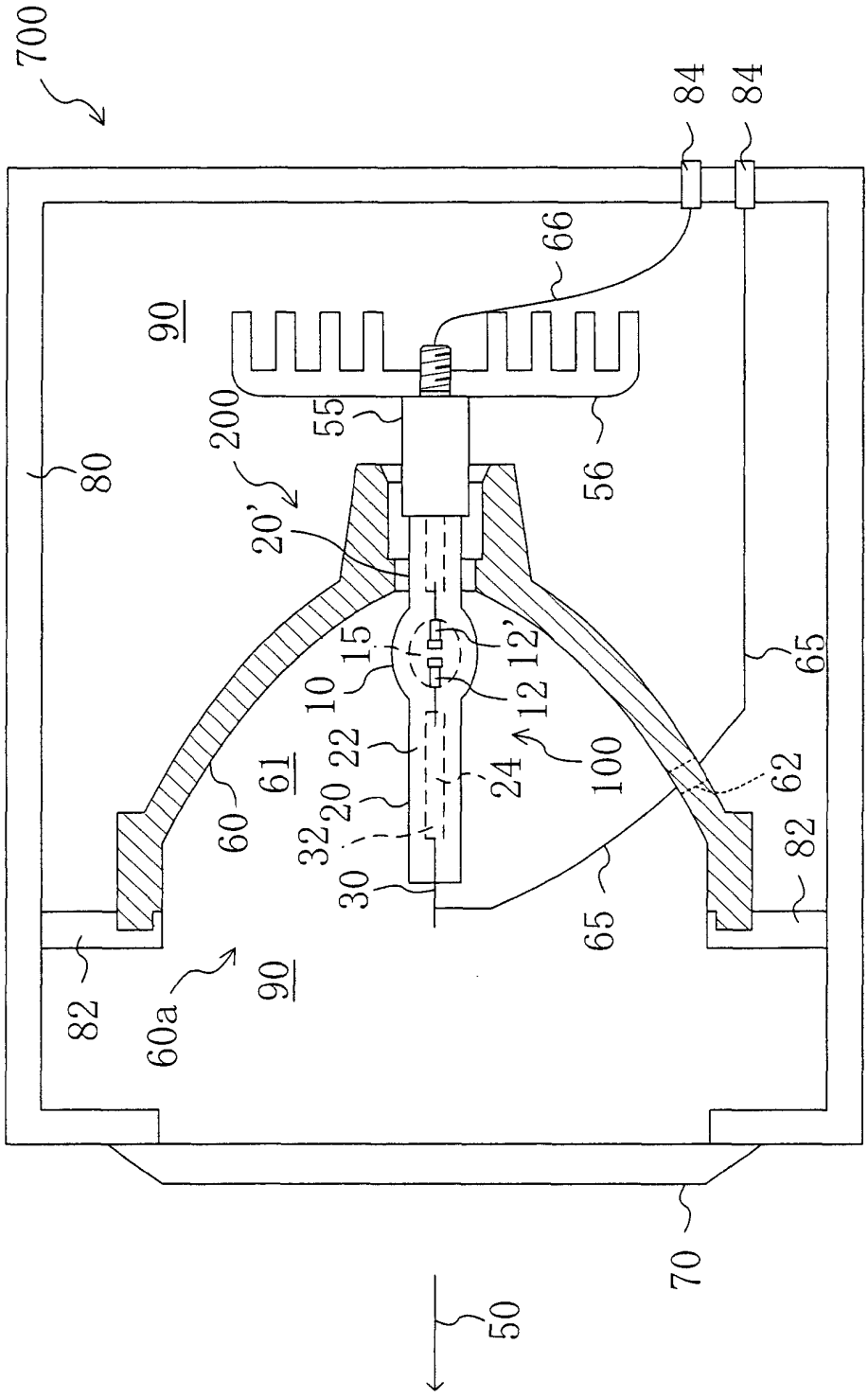
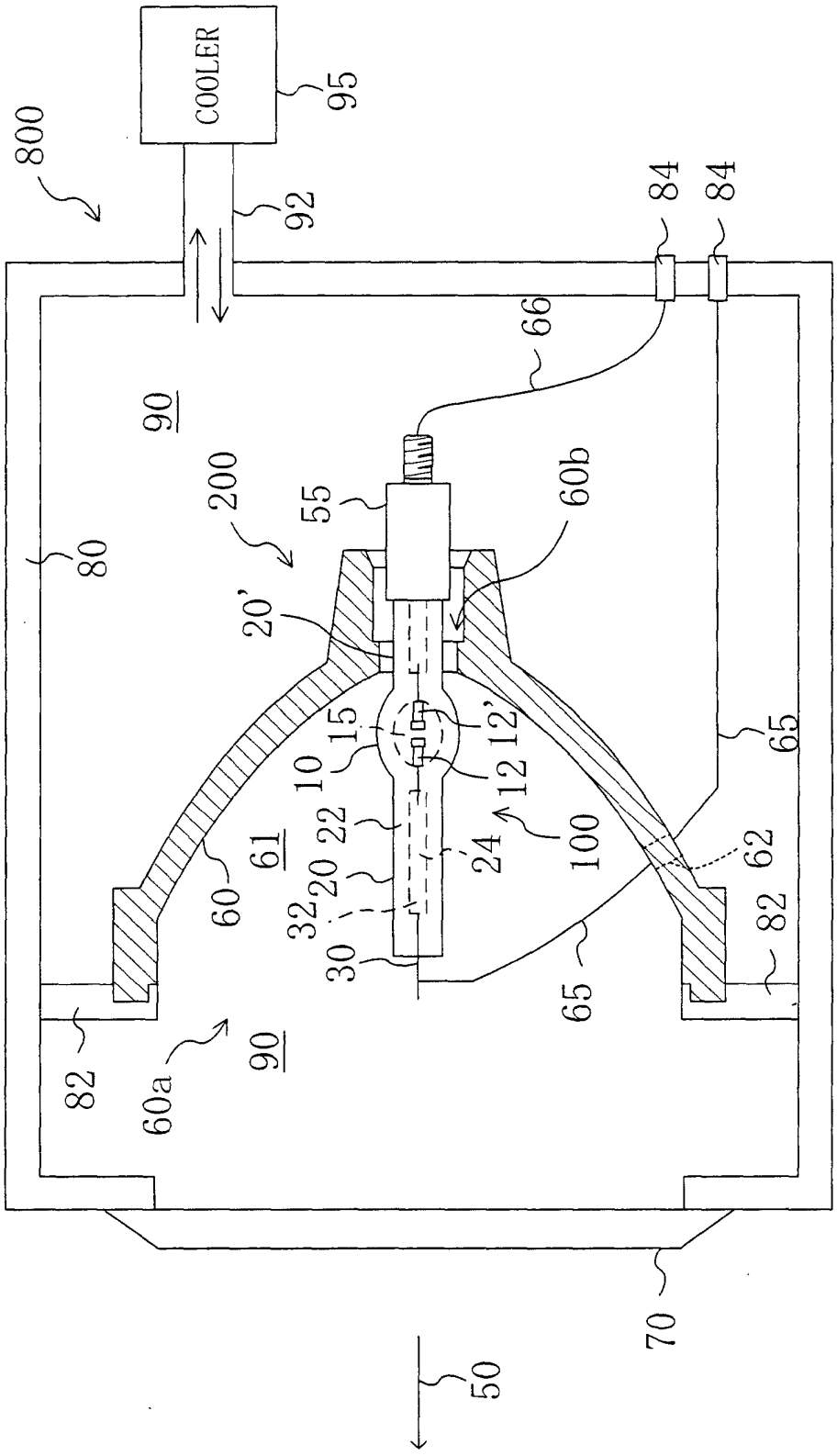

700
84
84
66
90
200
55
56
80
20'
15
12'
10
12
65
22
61
24
100
62
60
20
32
30
82
65
82
90
60a
70
50

FIG. 5


COOLER
95
800
92
84
84
66
90
200
55
60b
80
20'
15
10
12'
12
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100
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60
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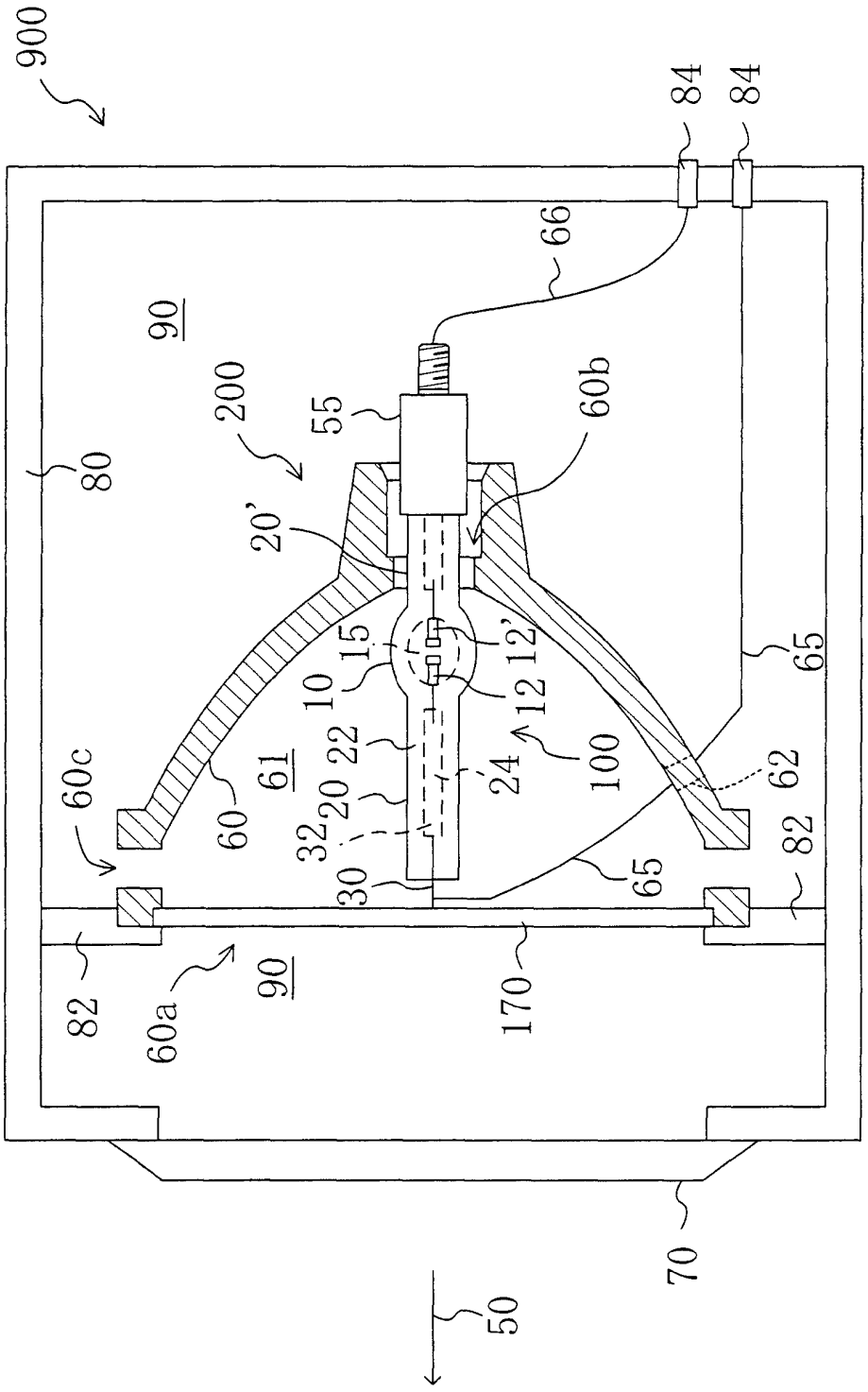
82
30
65
90
82
60a
70
50

FIG. 6


900
84
84
66
90
200
55
60b
80
20'
15
12'
10
12
65
22
24
100
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60c
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60
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32
82
30
65
82
60a
90
170
70
50

FIG. 7

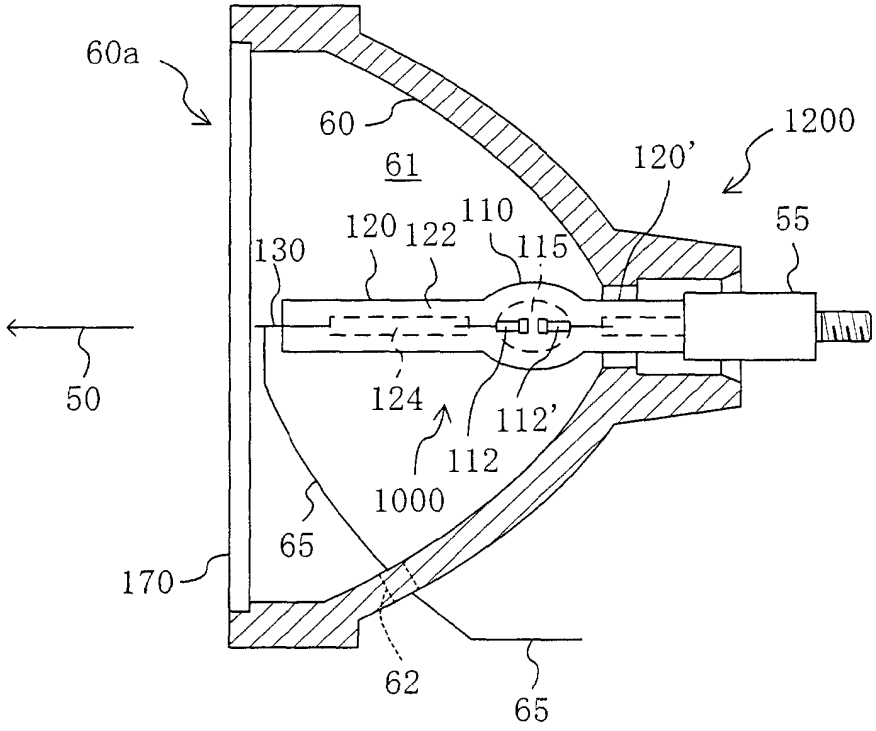
60a
60
61
1200
120'
55
110
120
122
115
130
50
124
112'
112
1000
65
170
62
65

FIG. 8A

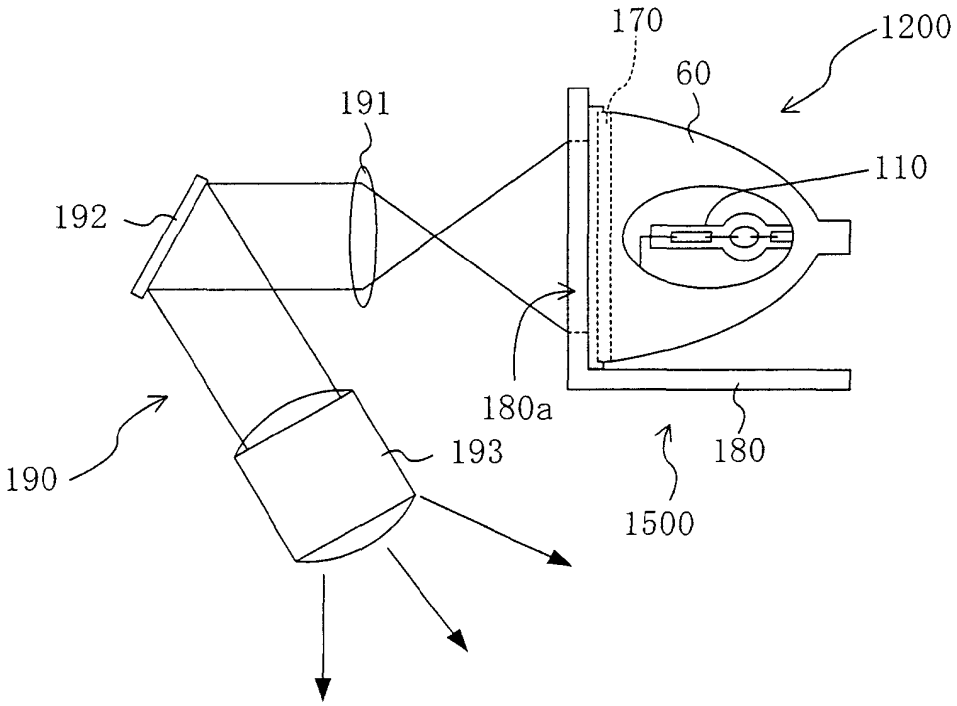


FIG. 8B